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Astronomy Group

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Reseach Activities

(I) STARS AND BLACK HOLES

a. stellar structure

UMEZU[1] extended the non-local mixing theory of stellar convective cores by Maeder to include the effects of radiative heat loss tends to enlarge the overshooting region, although it barely changes the size of the overshooting core

for the ordinarily accepted size of the convective element. The helium gradient seems negligible in the overshooting region.

NAKAKITA[2] studied the redistribution of angular momentum caused by the meridional circulation in a rotating Cowling-type star as a nonlinear initial-value problem, employing the first-order perturbation theory and Legendre expansion. He have found that the difficulty of the Eddington-Sweet theory, that is, the meridional velocity becomes infinitely large both on the free surface and on the interface between the radiative and convective regions, is removed following Osaki's (1972) or Sakurai's (1975) proposal. His work shows that the star moves toward the almost circulation free state in the Eddington-Sweet time-scale. However, the resultant almost circulation free state is quite different from the Roxburgh solution; the random circulation argued by Kippenhahn never appears.

b. stellar pulsation

ZALEWSKI[3] described a method for the solution of gray radiative transfer in a spherical, pulsating atmosphere. His program was used to study the begavior of the emergent intensity and to compare the properties of pulsations in radiative transfer and diffusion approximations. He has found that the emergent intensity exhibits an oscillating peak in layers in which the light starts to pass through the atmosphere. The peak is nearly absent in the cepheid model, while it is present in more less massive and bluer models than that of cepheids. In the extremely less massive models, the periods and stabilities of pulsation modes determined by the radiative transfer models differ significantly from those obtained using a diffusion approximation.

ZALEWSKI[4] discused the properties of linear nonadiabatic pulsations for radial and nonradial acoustic modes in low-mass supergiant stars in the diffusion approximation and with radiative transfer. Although strange modes are found both for radial and nonradial modes, heir frequencies and excitation rates depend sensitively on the description of the outer stellar layers. He used an asymptotic WKB analysis which takes into account the strong nonlinearity in entropy perturbation, to examine the influence of nonadiabaticity on the pulsation modes. He has found that for strong nonadiabaticity two types of modes are possible, viz. either ordinary or strange modes.

ZALEWSKI[5] discussed the observational data on variable intermediate spectral type supergiant stars and pulsational models applicable to these stars. TAKEUTI[6] discussed the general properties of the UU Her stars, and pointed out the pulsation mass of UU Her can be calculated by using the linear calculations by Takeuti and Petersen based on its double periodicity.

TAKEUTI and ZALEWSKI[7] calculated linear nonadiabatic periods and

stabilities of radial pulsation for a model δ Scuti star. They also calculated adiabatic coupling coefficients. The transfer of pulsation energy among various modes were discussed briefly.

On nonlinear model oscillators TAKEUTI and TANAKA [8] continue their study, and published a note on analytical properties of the nonlinear one-zone stellar models. SEYA, TANAKA, and TAKEUTI[9], and TANAKA, SEYA, and TAKEUTI[10] studies coupling of two simple model oscillators mimicking nonlinear stellar pulsation. They published the Poincaré sections and the phase-locking state with various strength of coupling.

ISHIDA and TAKEUTI[11] revised a criterion for double-mode pulsation in oscillator model equations with two-mode nonresonant coupling. By applying the criterion, they demonstrated that there are four cases, namely, mode 0-only, mode 1-only, either-or, and double-mode ones on limiting amplitude space. They also showed that models with evolutionary masses are preferable for double-mode pulsations. Moreover, we study mumerically modal selection properties of the oscillator model equations corresponding to various limiting amplitudes. The results show the suggested criterion to be useful for prediction of modal selection properties. Some examples of the phase-locking behaviors are also shown.

ISHIDA and TAKEUTI[12] have compared a hydrodynamic model of a classical cepheid containing 500 grid points with that containing 100 grid points. In linear models, the growth rates of the pulsation modes appear to grow as the number of grid points increases, and to saturate at about 200 meshes. In hydrodynamic models, some shock phenomena appear to be captured only for a 500 grid-models. The usefulness of a fine-grid model is indicated for studying the shock waves in a pulsating envelope. A newly constructed 500-grid model was applied to a study of the ionization/recombination fronts ans shock waves in pulsating envelopes. The motion of discontinuity over an entire pulsation cycle was shown for the first time. At the minimum radius phase they have found that (1) the shock wave in the ionized region generates much heat energy, and that (2) the radiative flux significantly increases at the shock wave in the atmopsphere. The above two results indicate that the inclusion of convective energy transport and/or that of improved radiative transfer may affect the behavior of a hydrodynamic model with a strong shock.

c. black holes

The third law of black-hole thermodynamics, if it holds, insists that the temperature of black holes can never be decreased to the absolute zero through any finite thermodynamic processes. However, some of the accretion models proposed so far violate this law. OKAMOTO and KABURAKI[13] derived a

restriction which the third law demands for the accretion processes onto Kerr black holes.

The thermodynamic formulation of black hole mechanics is possible not only for holes' outer horizons but also for their inner horizons. OKAMOTO and KABURAKI[14] derived new relations in the context of the inner-horizon thermodynamics. Their physical relevance to the outside world is, however, not so clear at present.

Publications

1) The Effects of Radiative Heat Loss from the Convective Element, and of Helium Flux, on Overshooting in Stellar Convective Cores, M. Umezu, *Mon. Not. R. astr. Soc.* **252** (1991) 59 = *Sendai Astronomiaj Raportoj* N-ro 380.

2) Meridional Circulation in Rotating Stars, T. Nakakita, *Astrophys. Space Sci.* **188** (1992) 381 = *Sendai Astronomiaj Raportoj* N-ro 382.

3) Supergiant Pulsations with Gray Radiative Transfer in the Atmosphere , J. Zalewski, *Publ. Astron. Soc. Japan* **43** (1991) 345 = *Sendai Astronomiaj Raportoj* N-ro 381.

4) Strongly Nonadiabatic Pulsations and Strange Modes, J. Zalewski , *Publ. Astron. Soc. Japan* **44** (1992) 27 = *Sendai Astronomiaj Raportoj* N-ro 388.

5) Modelling Supergiant Pulsations, J. Zalewski, *Sci. Reports Tôhoku Univ. 8th Ser.*, **12** (1992) 157 = *Sendai Astronomiaj Raportoj* N-ro 390.

6) Comment on an Enigmatic Star, UU Her, M. Takeuti, *Sci. Reports Tôhoku Univ. 8th Ser.*, **12** (1992) 145 = *Sendai Astronomiaj Raportoj* N-ro 390.

7) Structure of Modal Coupling in a δ Scuti Star Model, M. Takeuti and J. Zalewski, *Delta Scuti Stars Newsletter* **4** (1991) 14.

8) Note on the Model Oscillatiors of Irregular Stellar Variability, M. Takeuti and Y. Tanaka, *Astrophys. Space Sci.* **180** (1991) 157 = *Sendai Astronomiaj Raportoj* N-ro 378.

9) The Poincare sections of a Model Oscillator for Stellar Pulsation, K. Seya, Y. Tanaka, and M. Takeuti, *Bul. Fac. Educ., Ibaraki Univ. (Nat. Sci.)* **40** (1991) 1.

10) The Phase-Locking Satates for Changes of Coupling Coefficients of Two-Mode Coupling Models for Stellar Pulsations, Y. Tanaka, K. Seya, and M. Takeuti, *Bul. Fac. Educ., Ibaraki Univ. (Nat. Sci.)* **41** (1992) 37.

11) Modal Selection in Oscillator Model Equations with Two-Mode Nonresonant Coupling, T. Ishida and M. Takeuti, *Astrophys. Space Sci.* **178** (1991) 311 = *Sendai Astronomiaj Raportoj* N-ro 371.

12) Shock Phenomena in a Hydrodynamic Model of a Classical Cepheid, T. Ishida and M. Takeuti, *Publ. Astron. Soc. Japan* **43** (1991) 795 = *Sendai Astronomiaj Raportoj* N-ro 387.

13) The Third Law of Thermodynamics of Kerr Black Holes, I. Okamoto and O. Kaburaki, *Mon. Not. R. astr. Soc.* **250** (1991) 300 = *Sendai Astronomiaj Raportoj* N-ro 376.

14) The "Inner-Horizon Thermodynamics" of Kerr Black Holes, I. Okamoto and O. Kaburaki, *Mon. Not. R. astr. Soc.* **255** (1992) 539 = *Sendai Astronomiaj Raportoj* N-ro 386.

(II) GALAXIES

CHIBA[1] studied further properties of the resonance of galactic dynamos under the influence of galactic density waves. Two-dimensional numerical calculations were performed to elucidate the characteristic structure and evolution of the excited magnetric fields in a galactic disc. Models subject to spiral-arm perturbations of the α-effect were considered as well as those with perturbations of the gaseous velocity fields. It has been shown in the state of complete resonance, the magnetic fields exhibit a steady growth of energy without any oscillations. The whole pattern of magnetic fields remains unchanged with time, but propagates just with the imposed disturbances parallel to the galactic plane. The field structure excited is found to be largely influenced by the spatial form of disturbances in the velocity fields and α-effects; for example, the wavelength of excited fields is just twice that of density waves.

KIMURA and TOSA[2] presented results of hydrodynamical simulations of a cylindrical gas cloud strongly pushed by a surrounding high-pressure gas. They introduced a perturbation on the closed surface and numerically follow its evolution. A distortion of the shocked shell increases as the shell converges toward the center, and high-density gas clumps are formed behind the perturbed shock. The gas clumps gradually separate from the shell and eventually drift in the surrounding hugh-temperature region. For parent coulds with initial radius of 5-50 pc and density of 20-270 cm^{-3}. gas clumps are formed in the order of 10^6 yr. Their size and density are 0.1-3.0 pc and 10^2-10^4 cm^{-3}, respectively, so their mass is several hundreds of solar masses, which is larger or close to the local Jeans mass. These physical properties of gas clumps are very similar to those of isolated dark globules, suggesting new mechanisms for the origin of isolated dark globules and stars.

FUKUNAGA and TOSA[3] have studied the dynamical behavior of a self-gravitating gaseous disk in the central region of a galaxy in response to a fixed,

ovally distorted gravitational potential. The gas disk was modeled as an ensemble of inelastically interacting gas clouds and followed using an N-body simulation. To observe the behavior of gas near the center they simulated gas flow within a few turn-over-radii of the rotation curve. The gas accumulates and forms an oval ring type to an outer differential type. As the self-gravitation of the gas increases, the ring becomes asymmetric and a large gas clump appears at either end of the major axis of the bar; if the gas mass amounts to more than 10% of the total mass, the asymmetry of the flow and gas clumping increases, the gas flow becomes highly unsteady and occasionally the gas passes through the very center of the galaxy, indicating a dynamical inflow of gas to the center. The authors argued that this could provid a fueling mechanism for activities in galactic nuclei.

KUMAI and TOSA[4] presented an attempt to explain the widespread distribution of irregulars blue compact galaxies in the metallicity (Z) - gas mass fraction (μ) diagram in the framework of the closed-box model of chmical evolution. The differences in Z for the same value of μ among galaxies are ascribable to those in the mass fraction of dark matter which does not participate in the chemical evolution. They evaluated the mass fraction of dark matter for each galaxy required for the simple model to yield the observed matallicity Z for the observed gas mass fraction μ. If a chemical yield of $y = 0.01$ is adopted, the dark-matter fraction shows good correlations with the mass-luminosity ratio and the dark-matter fraction obtained independently of the chemical composition. These results lead to the following suggestions: these galaxies contain various fractions of dark matter which do not take part in the chemical evolution; their Z-μ relation follows that of the simple model modified to include the dark matter; the chemical yield of these galaxies is close to that conventionally used for the chemical evolution of the solar neighborhood.

Publications

1) Spiral-Arm Resonance in Galactic Dynamos, M. Chiba, *Mon. Not. R. astr. Soc.* **250** (1992) 769 = *Sendai Astronomiaj Raportoj* N-ro 377.

2) Globule Formation in a Disturbed Converging Shock, T. Kimura and M. Tosa, *Mon. Not. R. astr. Soc.* **251** (1991) 664 = *Sendai Astronomiaj Raportoj* N-ro 379.

3) Dynamics of a Self-Gravitating Gas Disk in an Ovally Distorted Gravitational Potential, M. Fukunaga and M. Tosa, *Publ. Astron. Soc. Japan* **43** (1991) 469 = *Sendai Astronomiaj Raportoj* N-ro 384.

4) Metallicity and Gas Mass Fraction in Irregulars and Blue Compact Galaxies: the Effect of Dark Matter, Y. Kumai and M. Tosa, *Astron. Astrophys.* **257** (1992) 511 = *Sendai Astronomiaj Raportoj* N-ro 393.

(III) OBSERVATIONS

TAMURA and TAKEUTI[1] and TAMURA, ZALEWSKI and TAKEUTI[2] reported the results of their spectroscopic observations of five F supergiant stars which show the variability of Hα profiles, and discussed related data.

Publications

1) Spectroscopic Observations of Five F Supergiant Stars, S. Tamura and M. Takeuti, *Inf. Bull. Var. Stars*, **3561**.
2) Spectroscopic Observations of F Supergiant Stars and a Summary of Related Data, S. Tamura, M. Takeuti, and J. Zalewski, *Sci. Reports Tôhoku Univ. 8th Ser.*, **12** (1992) 145 = *Sendai Astronomiaj Raportoj* N-ro 390.

(IV) NEW INSTRUMENTS

The following instruments were purchased:

Workstations
Titan 750 system (Kubota Computer),
Mips 3220 system (Kubota Computer);

X-terminal
VDS VXW-80 (Victor Data Systems);

Personal computer
PC9801DA system (NEC).

Doctor Thesis

D1) Supergiant Pulsation,
Jan Zalewski
D2) Perturbation Theory of Relativistic Magnetohydrodynamic and Its Application to Black Hole Magnetospheres,
Toshio Uchida

Master Thesis

M1) Extraterretial Environments Possibly Yielding Life,
Akimichi Hirose

M2) High-Latitude Molecular Clouds,
Minoru Kawahara

M3) Numerical Experiments in Dynamics of the Galactic Disk,
Makoto Kojima

M4)Dark Matter in Galaxies,
Kaori Oshio

M5) Formation and Evolution of the Galactic Disk,
Yasuhiro Shioya

M6) Application of Multi-Frequency Aperture Synthesis Method to Millimeter Wave Observation,
Mika Suzuki